REMARKS

Claims 16, 21, 29, 31, 33, and 38 have been amended to correct typographical errors therein. Claim 35 has been rewritten to place it in independent form. Claims 39 and 40 has been added. Claims 1-40 therefore are pending and presented for review. Favorable reconsideration and allowance are requested in light of the foregoing amendments and the remarks which follow.

1. Prior Art Rejections

Claims 29 and 30 stand rejected under 35 USC 103(a) as being obvious over Zur Loye in view of Nozawa. Claims 32 and 34 stand rejected under 35 USC 103(a) as being obvious over Zur Loye in view of Nozawa as applied against claim 29, and further in view of Talbert. These rejections are respectfully traversed.

a. Recapitulation of the Invention[1]

By way of explanation, the relevant portion of the invention relates to an improved method for achieving homogeneous charge compression ignition (HCCI) in a liquid fueled engine, such as a diesel engine. HCCI has many benefits over conventional ignition because it has no throttling losses. Hence, combustion occurs simultaneously throughout the cylinder rather than as a flame front.

[1] This section 1(a) is presented for background purposes so the Examiner may understand the state of the art and, in general terms, the applicant's contribution thereto. It is not intended to constitute a specific traversal of any particular rejection. That task instead is performed in Section 1(b) below.

Much work has been done to optimize HCCI ignition in a conventional dual fuel engine, i.e., one having a gaseous fuel such as natural gas as a primary fuel and a liquid fuel such as diesel fuel as a pilot fuel. HCCI is relatively easy to achieve if the primary fuel is provided in a gaseous form because a gaseous fuel has a different autoignition temperature than the pilot fuel. On the other hand, little work has been done to date in *liquid* fueled HCCI engines because, *inter alia*, it is difficult to introduce the primary fuel in a vapor state and to homogeneously mix it with air.

The inventors have solved this problem in a relatively simple and effective manner by introducing the primary fuel engine in the form of finely atomized liquid droplets having a diameter of less than about 50 microns and, more preferably, less than about 30 microns. The resulting small liquid droplets mix rapidly with the air stream when it is injected into the air intake system of the HCCI engine so as to form a homogenous charge. Specifically, the injected fuel enters the intake stream as a finely atomized mist formed from millions of micron sized droplets and rapidly vaporizes to form a homogenous mixture of the intake air. The homogenous mixture is not only well-suited for HCCI combustion but can also increase the turbo boost of air mass if the fuel is injected into the air intake system upstream of a turbo charger compressor inlet. Droplet evaporation also provides air charge cooling, reducing the load on the engine's aftercooler, if present.

The atomized droplets can be produced using a so-called MeeFog® nozzle traditionally used to supply cooling water to a gas turbine. Referring to Fig 18 by way of

example, one system configured in this manner uses a Meefog nozzle 532 to inject a liquid fuel into the engine's air intake manifold 434. The micron-sized droplets of liquid fuel are then mixed with incoming air and drawn into the combustion chamber 418 through the cylinder's air intake passage 426. The mixture is then pilot ignited through HCCI with the aid of pilot fuel injected directly into the combustion chamber 418 via an injector 432.

b. Traversal of Rejection

With respect to claim 29, the Examiner contends that Zur Loye discloses all that is claimed except for the production of atomized droplets of fuel having a diameter of less than 50 microns and that it would have been obvious, in view of the teachings of Nozawa to replace Zur Loye's primary fuel source with one providing atomized fuel in the droplet diameter claimed. This rejection is improper because there is no motivation to combine the prior art to produce the claimed invention.

Specifically, claim 29 recites, *inter alia*, injecting a *liquid* fuel into an air stream so as to form a homogenous mixture of air and atomized droplets of fuel having a mean diameter of less than 50 microns, admitting the mixture into a combustion chamber of an IC engine, and then igniting the fuel by compression ignition so as to achieve HCCI. None of these steps is disclosed or suggested by the prior art relied upon by the Examiner.

Zur Loye generally describes recent work on HCCI engines. First and second fuel supply sources 32 and 34 are described for supplying "fuel" to the intake duct 26 at the outlet of a cooler 28. Page 4, lines 17-20. A fuel injector 36 is also disclosed for injecting fuel directly into the combustion chamber. Col. 5, lines 3-4. A separate injector 42 is disclosed for injecting a diluent into the intake duct 26. Page 5, lines 1-2. Hence, contrary to the Examiner's assertions, element 42 does not deliver the fuel to Zur Loye's engine.

The Examiner acknowledges that *no* device disclosed in Zur Loye injects a liquid fuel into an air stream so as to form a homogeneous mixture of air and atomized droplets of the claimed diameter. He contends that it would have been obvious, in view of the teachings of Nozawa, to correct this deficiency. However, the teachings of Nozawa are in no way applicable to Zur Loye.

Nozawa discloses an air assisted injector for injecting fuel into an intake port of a gasoline powered Otto cycle or spark ignited engine. Combustion characteristics of an Otto cycle engine fueled by gasoline are entirely different from a gaseous fueled or even liquid fueled HCCI engine. To say that an injector usable in the former could be used to supply fuel to the latter compares apples to oranges. Moreover, the air assisted injector disclosed in the Nozawa patent operates on an entirely different principle than the fogging nozzle disclosed in the present invention and is utilized for a different reason having no applicability to an HCCI engine. Specifically, as discussed above, the applicant has discovered that the atomized droplets promote the formation of a

homogeneous mixture in the combustion chamber and also increases the turbo boost of the air mass if the fuel is injected into the air injector system upstream of the turbo charger compressor inlet. In contrast, the injector 18 of Nozawa is utilized to prevent the injected gasoline from wetting the intake port walls. See col. 1, lines 55-66 and col. 2, lines 6-10. Along these lines, the injector *selectively* supplies fuel in the form of atomized droplets. The droplets are atomized using air assistance provided by a pump. Importantly, however, fuel is injected in an atomized form only in the low/medium speed and low/medium load regions of engine operation. Atomization is said not to be required in high speed or high load region of the engine operating range where the face temperature of the intake valve is relatively high because the desired fuel atomization is promoted by the valve face of the high temperature. Col. 2, lines 19-22. This variable fuel atomization control principle is applicable only to fuels, such as gasoline, that have a relatively low boiling temperature. It is inapplicable to diesel fuel or other compression ignition fuels having high boiling temperatures. Nor is port wetting discussed as being of a concern in Zur Loye. Nor is there any indication in Nozawa that port wetting would be a problem in an HCCI engine. The rejection should be withdrawn for this reason alone.

Other aspects of Zur Loye's system counsel against combining Zur Loye with Nozawa in a manner that would produce the claimed invention.

For instance, the fuel supplies 32 and 34 of Zur Loye appear to supply *gaseous* fuels rather than liquid fuels. Applicant bases this conclusion on the fact that 1) research prior to the development of the invention focused on HCCI of gaseous fuels, 2) no

specific fuels are described for the supplies 32, and 34, leading one to conclude that the supplies 32 and 34 supply traditional fuels combustible by HCCI, i.e., gaseous fuels, and 3) the only reference to diesel fuel comes on pages 5 and 6 of the Zur Loye publication, which states that diesel fuel may be injected directly into the cylinder via the injector 37 and used as a pilot fuel for gaseous fuels supplied in the intake manifold or as the engine's only source of fuel. The injector 18 of Nozawa supplies only a *liquid* fuel, i.e., (gasoline) to the intake manifold and, therefore, could not be used to replace the gaseous fuel sources 32 and 34 of Zur Loye. Simply put, *neither* reference suggests that a liquid fuel could be supplied to an intake manifold of an HCCI engine.

In addition, Zur Loye's fuel supplies 32 and 34 supply fuel to the air intake stream *downstream* of the cooler 28. Page 4, lines 1-2. Locating an atomizing injector downstream of Zur Loye's cooler 28 would inhibit atomization because less energy would be available in the cooled air to vaporize the fuel. Zur Loye therefore teaches away from the proposed combination for this additional reason.

In light of the foregoing, applicant submits that the cited Zur Loye and Nozawa references, when considered as a whole, do not suggest combining the references so as to produce the invention of claims 29 and 30.

The rejection of claims 32 and 34 in view of Nozawa and further in view of Talbert is also traversed. As discussed in the response to the first Office Action, Talbert merely discloses that it is known to use a fogging nozzle 99 of a particular type to supply atomized gasoline to a carburetor. Col. 1, lines 18+. There is no indication that its

particular fogging nozzle would produce liquid droplets of the claimed size. Nor is there any suggestion whatsoever that the particular nozzle and associated fuel source of Talbert are suitable for supplying liquid fuel to an HCCI engine.

Moreover, Nozawa teaches directly away from the proposed combination. As discussed above, an important feature of Nozawa is the utilization of an air supply pump to *selectively* provide pressurized air assistance to atomize the fuel supplied by the injector 18. The pump is disabled at high loads and high engine speeds. If one were to replace Nozawa's injector 18 with the fogging injector disclosed in Talbert, the ability to selectively disable the injection of atomized fuel would be lost.

4. New Claims, Allowable Subject Matter and Conclusions

New claim 39 depends from claim 29 and additionally requires that the injecting liquid fuel into the air stream in the manner recited in claim 29 be performed on a full range of engine speeds and operating loads. In contrast, and as discussed above, the cited Nozawa patent teaches directly away from this aspect of the invention by selectively disabling the pressurized air assistance and injecting atomized fuel only at low and medium speed load conditions.

New claim 40 depends from claim 29 and requires that the liquid fuel be injected into the air intake passage upstream of a turbocharger. In contrast, all fuel (as opposed to diluents) supplied to Zur Loye's intake passage are supplied downstream of the cooler 28.

The indication of the allowability of claims 1-28, 31, 33, and 38 and of the presence of allowable subject matter in claims 35-37 is noted with appreciation. By this amendment, claim 35 has been rewritten in independent form to include the limitations of claim 29 from which it depends.[2] Because the remaining rejections have been overcome and/or are traversed for the reasons discussed above, all claims are now believed to be in *prima facie* condition for allowance. Withdrawal of all rejections and allowance of the application therefore are believed to be in order and are respectfully requested. Should there be any remaining questions the attending to of which would help expedite such matters, the Examiner is requested to contact the undersigned at the telephone number appearing below.

[2] Applicant intended to rewrite claim 35 in independent form in the response filed August 30, 2004 but inadvertently failed to do so.

A check in the amount of $300 in payment of the fee associated with two additional claims in excess of 20 and one additional independent claim in excess of three by a *large* entity. No additional fee is believed to be payable with this communication. Should the Examiner consider any other fees to be payable in conjunction with this or any future communication, the Director is authorized to direct payment of such fees, or credit any overpayment to Deposit Account No. 50-1170.

Respectfully submitted,

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